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Consolidated Slip Cleanup Project - Recommended Work Plan Elements for Contaminated Sediment Management Aspects of Dredging, Capping, and CDF Placement

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Introduction

Objective

This document provides a description of recommended work plan elements (essentially recommended technical evaluations) for the Consolidated Slip Cleanup Project related to sediment management aspects of dredging, CDF placement, and capping. The descriptive information in this document provides a basic rationale for each area of evaluation and the technical basis of the evaluation. These descriptions were adapted from commonly used references and guidance documents for sediment management and remediation, dredging, CDF design, and subaqueous capping. Recommended work plan elements (e.g., sampling, testing, modeling, design evaluations, etc.) are shown as *italicized bulleted lists* following the respective descriptions.

Background

The concept for the project involves the construction of a new channel in the western portion of Consolidated Slip and a marina development in the eastern portion of Consolidated Slip. DMJM Harris has conducted a Hydraulic Study to determine the optimum design of the new Dominguez Channel Extension. The Dominguez Channel upstream of Consolidated Slip is essentially a slack water channel for much of the time, but subject to flood flow. The Dominguez Channel Extension must therefore be designed to provide proper flow conveyance. The Hydraulic Study by DMDJ Harris examined alternative geometries of the channel and determined that a bottom elevation of -37 ft MLLW with a 200 ft bottom width is optimum. This design leaves sufficient room for the marina development and protective rock berms to shield the marina from upstream recontamination. The Dominguez Channel Extension will be depositional, and there is potential for accumulation of new contaminants. Maintenance dredging in the channel must be accounted for, and one benefit of this project could be source control for Dominguez Channel until all the upstream sources are finally controlled.

The proposed cleanup project involves the following major actions related to contaminated sediments management:

- Dredging contaminated sediments from the eastern portion of Consolidated Slip to create an extension of Dominguez Channel;
- Dredging contaminated sediments from the western portion of Consolidated Slip to create water depths suitable for placement of a subaqueous isolation cap and later development of a marina;
- Placement of dredged sediment from Consolidated Slip in a Confined Disposal Facility (CDF) constructed at the Berth 243-245 site (the CDF); and,

- Construction of a subaqueous isolation cap over the western marina portion of Consolidated Slip.

Although the POLA objectives include the benefits of the new marina and associated developments, this project will be viewed by USEPA and the State environmental agencies as primarily a sediment remediation project. Technical considerations related to the contaminated sediment management aspects of each of these major activities is provided in outline form in this memo.

CERCLA Process

The CERCLA process for the OU2 (Dominguez Channel) portion of the larger CERCLA project is in the Remedial Investigation stage. DDT is the contaminant of concern (COC) for the CERCLA project, even though other COCs are present in the Consolidated Slip. There has been a buyout for OU2, and EPA Region 9 has funds available for CERCLA studies but no funds for the actual cleanup.

EPA Region 9 would like to pursue a Non-Time-Critical Removal (note that Removal in this context refers to removal of the risk, not dredging removal), and this involves preparation of an Engineering Evaluation/ Cost Analysis (EE/CA) report for the proposed cleanup project (which is similar to a CERCLA Feasibility Study). EPA is now working to complete an evaluation of water quality and food chain issues that would provide a basis for pursuing the EE/CA route for CERCLA (SQUIRP is doing this work). EPA seems generally supportive of the POLA proposal and envisions an 18 month timeline to complete work toward an approval to place the CERCLA material in a CDF at Berth 243-245. The POLA is proceeding to identify the elements of a work plan to provide EPA with the site information, sediment data, and capping and CDF design features to support the EE/CA. This document describes work plan elements for the contaminated sediment management aspects of dredging, CDF design, and capping.

Sediment Characterization and Site Conditions

Sediment Characterization

Several sediment investigations at both the Consolidated Slip location and the location of the CDF have been completed. However, additional field investigations may be needed.

Fifteen 20 ft long cores were collected in Consolidated Slip in October 2002 (AMEC Inc. 2003). Samples were analyzed for concentrations of metals, DDT and derivatives, PAHs, and PCBs. These data essentially provided a general overview of the distribution and levels of contamination in Consolidated Slip.

Twenty seven cores were taken in Consolidated Slip as a part of the 2006 Marine Exploration Program (draft Kinnetic Labs). Samples were analyzed for concentrations of metals, organotins, pesticides, PCBs, and PAHs. These data provide a more refined view of contaminant distribution in Consolidated Slip. In addition, Effluent Elutriate Tests (also called modified elutriate tests) were performed on 9 composite samples from top and bottom horizons in specific areas of Consolidated Slip.

Geotechnical borings were taken by Fugro West Inc. as a part of the 2006 Marine Exploration Program at both the Consolidated Slip and at the Berth 243-245 site. These investigations included soil classifications and CPT profiles. Presumably, additional geotechnical data are presently pending. Vibracores for analysis of sediment chemistry were also taken at the Berth 243-245 site.

Recommended Work Plan Elements:

- *Detailed review of the existing physical and chemical data to determine requirements for additional sampling and investigations.*
- *Possible collection of samples from the proposed dredge cut materials for purposes of dredging release testing and CDF pathway testing.*
- *Possible collection of samples from the marina portion of the Consolidated Slip lying below the proposed cap for cap effectiveness testing.*

Site Conditions

An assessment of site conditions at the Consolidated Slip will be required to evaluate dredging releases and for design of the cap. An assessment of site conditions at Berth 243-245 will be required for design of the CDF. The site conditions of importance for dredging, CDF placement, and capping are separately listed in the appropriate sections below.

Source Control

USEPA has indicated in its Sediment Remediation Principles that no sediment remediation project should be performed without due consideration of source control issues. Source control is an issue for this project, since contamination in Dominguez channel would not be addressed prior to implementation of the Consolidated Slip project. There are many sources in Dominguez Channel, and complete control is not practical. CH2MHill is doing work for EPA on Dominguez Channel, and results of this work may provide information regarding potential recontamination issues in Consolidated Slip.

Both the marina portion and especially the channel portion and sedimentation basin will be recontaminated over time. The design of the cap over the marina portion and the plans for maintenance of the channel portion must consider the rate of sediment accumulation and contamination and appropriate management approaches.

Dredging at Consolidated Slip

Dredging Operations

Evaluation of an environmental dredging project includes the following: defining objectives of the dredging component of the remedy; initial determination of the feasibility of dredging; identification of data gaps; site and sediment characterization to support the evaluation of dredging; determining the removal requirements; developing performance standards; selecting dredging equipment types suitable for the project; estimating production rates and duration of the project; evaluation of sediment resuspension, contaminant release, and residuals; consideration of control measures; and development of operations and monitoring plans (Palermo et al 2006). Many of these aspects will be evaluated as a part of the production dredging project design. For example, the conventional analysis of production rates, project duration, etc. will be considered in the normal course of developing the plans and specifications for the dredging.

Since the project is a CERCLA removal action, the dredging should be evaluated as an environmental dredging project, with sediment remediation as a stated goal of the work. The objectives of environmental dredging would normally include:

- Dredge with sufficient accuracy such that contaminated sediment is removed and cleanup levels are met without excessive removal of clean sediment;
- Dredge the sediments in a reasonable period of time and in a condition compatible with subsequent transport for treatment or disposal,
- Minimize and/or control resuspension of contaminated sediments, downstream transport of resuspended sediments, and releases of contaminants of concern to water and air; and,
- Dredge the sediments such that residual sediment is minimized or controlled.

Dredging Performance Standards

Technical evaluations must be based on the ability of a given dredging design to meet performance or design standards. Performance standards may include applicable water quality and air quality standards, limitations on or minimum requirements for production, and standards for dredging effectiveness (usually defined in terms of meeting a cleanup level). The potential performance standards include those related to meeting Applicable or Relevant and Appropriate Requirements (ARARs) under CERCLA (or the equivalent requirements under other regulatory programs) and specific standards related to dredging performance.

Recommended Work Plan Elements:

- *Dredging Performance Standards should be defined specifically for this project. The Standards are assumed to be based on Federal and State water quality standards as normally addressed by 401 Certifications for navigation projects in the Port. Monitoring requirements would also reflect local precedent for 401 Certifications.*

Dredging Equipment Selection

Selection of equipment for implementation of the dredging project would normally be left to the contractor. However, dredge equipment type(s) and size(s) should be selected for design evaluations based on the site conditions, sediment characterization data available, past project experience for the POLA, and performance standards. Selection should be made considering pertinent equipment capabilities and selection factors related to the capabilities of equipment and the compatibility of equipment with site and sediment conditions, transport and rehandling requirements, and disposal options (Palermo and Francingues 2004 and EPA 2005). A preliminary operational strategy (to include a dredging sequence, depths of cuts, cut slopes, consideration of allowable overdredging, etc.) can be developed at an early stage.

Mechanical dredging with clamshell equipment and environmental buckets has been successfully used in the POLA, and this method is anticipated for the Consolidated Slip project. With mechanical dredging, the CDF can be partially enclosed, leaving access for disposal barges to enter the site. Material can be bottom-dumped for the initial stages of filling. Once the dike is completed, the material can be off-loaded from the barges and mechanically placed in the CDF.

Recommended Work Plan Elements:

- *Conduct an initial evaluation of dredging equipment types and sizes that would be most likely used for the Consolidated Slip dredging and define a preliminary operational approach for the work.*

Resuspension and Contaminant Release

The main contaminant issues related to the dredging portion of the project are sediment resuspension during dredging and subsequent contaminant release. Resuspension evaluations usually rely on an estimate of the resuspension "source strength", i.e. the mass of sediment resuspended per unit time, coupled with a model for prediction of suspended solids concentrations as a function of distance and time. These estimates can be based on field experience (a number of published papers have summarized resuspension data for completed dredging projects), or empirical or analytical models (e.g., the USACE DREDGE model). Results can then be compared to performance standards for resuspension or water quality standards for suspended sediments or turbidity. The need for control measures (such as restrictions on the rate and timing of operations or deployment of silt curtain containments) can then be determined.

Releases of contaminants of concern in dissolved phase to water and releases of volatile contaminants to air are directly related to sediment resuspension. At early stages of evaluation, the estimates of contaminant release may be based on simple partitioning models. For detailed evaluations, estimates could be based on laboratory tests such as the Dredging Elutriate Test (DRET) or flux chamber tests for volatilization. Results of both release evaluations and sediment resuspension evaluations can be used in combination to estimate concentrations of contaminants in the water column or volatilized to air, and these can be compared to water quality standards or air quality limits established for the project. As with sediment resuspension, these comparisons will determine the need for control measures.

Recommended Work Plan Elements:

- *Dredging Elutriate Tests (DRETs) should be conducted on composite sediment samples to evaluate contaminant release during dredging.*
- *The potential for volatile release during dredging should be assessed.*
- *Conduct evaluations of sediment resuspension due to dredging, associated release of contaminants and potential compliance with Water Quality Standards related to the dredging operation. The USACE DREDGE model and/or other dispersion models would be suitable for this evaluation.*

Residuals

There are issues with source control for this project, but the Consolidated Slip channel will be designed to accumulate sediments entering from Dominguez Channel. These factors indicate that dredging residuals should not be a major issue for project design and implementation. Some overdredging may serve to initially reduce the initial residual concentrations of COCs in the channel area.

Recommended Work Plan Elements:

- *Conduct an evaluation of the likely thickness, density and concentration of COCs in generated residuals (those resulting from the dredging operation) and the likely characteristics of undisturbed residuals (those in-situ residual sediments uncovered by the dredging operation).*
- *Determine the appropriate management approach for residuals.*

Operations Plan

Once the removal requirements are determined, dredge type and size selected, production rates evaluated, and need for additional controls for resuspension, release and residuals established, all information should be available to develop an operations plan. The plan should include a detailed dredging prism; delineation of dredging management units; description of dredge cuts, layback slopes, and box cuts; a sequence of operations; detailed mob-demob and construction timeline, complete descriptions of all equipment to be used; design and use of control measures; methods for monitoring progress and payment, etc.

Recommended Work Plan Elements:

- *Development of a recommended sequence of dredging for the channel and marina sections of Consolidated Slip.*
- *Development of a Operations Plan for the dredging operations.*

Dredging Monitoring Plan

A Monitoring Plan should be developed to ensure the various performance standards related to the dredging operation are met. The detailed Monitoring Plan should include the monitoring equipment and techniques to be used (e.g. specific instruments, sampling devices, coring equipment); the protocols for sampling, handling and testing of samples (e.g. numbers and locations for sampling, compositing schemes, and testing procedures); and a description of how the monitoring data will be interpreted. Dredging monitoring typically consists of turbidity monitoring and collection of water column samples. Residuals monitoring is also common, but may not be a consideration for the Consolidated Slip project. There should also be a Management Plan, established in advance, describing specific actions to be taken based on the results of the monitoring. Management actions would typically be developed in a tiered fashion, depending on the monitoring results, and may include provisions for additional or more intensive monitoring, a slow-down or cessation of operations, or implementation of control measures.

Recommended Work Plan Elements:

- *Development of a preliminary dredging monitoring plan to include recommended sampling and evaluation approaches, monitoring equipment and techniques, and management actions.*

Confined Disposal Facility at Berth 243-245

A CDF is an engineered structure consisting of dikes or other structures that extend above any adjacent water surface and enclose a disposal area for containment of dredged material, isolating the dredged material from adjacent waters or land (USACE/EPA 1992). CDFs are one of the most commonly considered alternatives for contaminated sediments from navigation projects and are also an option commonly considered for disposal of contaminated sediments dredged for purposes of sediment remediation.

The Consolidated Slip cleanup project is now being considered separately from the POLA deepening project, so as not to delay it. But the design of the CDF at Berth 243-245 is proceeding. Evaluations of the CDF would focus on design of the CDF such that it can be constructed with controls sufficient to accept the Consolidated Slip material. This essentially requires that contaminant pathways be evaluated to determine any needed modifications to conventional CDF design.

CDFs as a CERCLA Remedy Component

CDFs are recognized by the EPA Superfund Sediment Guidance (USEPA 2005) as an option for disposal of contaminated sediments at CERCLA sites. There are no prescriptive design features for CERCLA CDFs in the EPA guidance. This is appropriate, since a CDF for a CERLCA project would be designed based on the same principles as that for a CDF used for contaminated sediments dredged from navigation projects.

Placement of the Consolidated Slip sediments in a CDF would hold significant advantage for cost savings and time to complete the remediation as compared to options involving dewatering, rehandling and landfill disposal. There are a number of precedents for use of a CDF for CERCLA projects to include: Hamilton Harbor, Canada; Middle Waterway, Tacoma WA; St. Paul Waterway, Tacoma WA; Eagle Harbor near Seattle WA, and the Terminal 4 CDF now under consideration for the Port of Portland.

CDFs are containment options, and a major consideration is evaluation and design of control measures for the several potential contaminant pathways that may be applicable. The 2003 USACE Upland Testing Manual (UTM) lays out a tiered approach for such evaluations, the UTM procedures are recommended for evaluation of sediments slated for CDF placement at Berth 243-245.

There are two pending regulatory issues related to use of the Berth 243-245 CDF for placement of Consolidated Slip materials under CERCLA. First, the sediments are at present being considered a RCRA listed waste and RCRA characteristic waste. There may be prescriptive requirements for CDF containment features under RCRA (such as double synthetic liners or leachate collection). EPA is now reviewing the regulatory information regarding equivalency alternatives. Second, the EPA (and/or the State of California) is considering the potential application of RCRA Land Disposal Restrictions which would essentially prohibit placement of the Consolidated Slip sediments at the site. Since the Berth 243-245 site is an in-water CDF, it would logically be regulated under the Clean Water Act, and any regulations for land disposal would not be applicable. However, these regulatory issues must be sorted out for the project design to go forward.

Recommended Work Plan Elements:

- *A regulatory determination must be made as to applicability of RCRA and the LDRs to the Berth 243-245 site.*

CDF Performance Standards

CDF design must be developed to meet applicable performance or design standards. Performance standards may include applicable water quality and air quality standards, The potential performance standards include those related to meeting Applicable or Relevant and Appropriate Requirements (ARARs) under CERCLA (or the equivalent requirements under other regulatory programs) and specific standards related to CDF performance. Of special importance are standards related to leachate quality, both in terms of numeric standards and appropriate points of compliance.

Recommended Work Plan Elements:

- *CDF Performance Standards should be initially defined in early phases of evaluation at least in general terms, and the standards should be refined and finalized in more specific terms in the later phases.*

Site Conditions at Berth 243-245

General categories of site conditions that should be considered in cap design include:

Water Depths and Bathymetry. The bathymetry data are available and should be adequate for determining volumetric capacity.

Hydrodynamic Conditions. An evaluation of hydrodynamics will be needed for assessment of barge bottom-dump filling operations and mixing/dispersion evaluations for effluent and leachate discharges.

Hydrogeological Conditions and Groundwater Flow. An evaluation of groundwater flow velocities into the CDF will be needed for leachate evaluations.

Presence of Debris. The presence of large debris in the berth should be identified but removal would not likely be necessary.

Recommended Work Plan Elements:

- *Conduct a detailed review of site conditions based on existing information and identify data gaps.*
- *Design any additional site investigations that may be required.*

CDF Layout and Operational Approach

The operational approach for using the Berth 243-245 CDF would be similar to that used for the Southwest Slip CDF in the POLA. This CDF was partially filled by barge bottom-dumping and the fill was completed by hydraulic pumping. About 1 million cubic yards of contaminated sediment, all unsuitable for open water disposal, was placed in the 25 acre site. The placement of a sand cover was problematic, and the surface material was rehandled to dry and replaced prior to placement of a sand and gravel layer and installation of wick drains (Mast and Foxworthy 2005).

Recommended Work Plan Elements:

- *A facility layout plan should be developed for the site, to include a conceptual description of the retaining structures, locations of entry/exit for barges, consideration of closure structures during barge access, locations of offloading* *facilities for final placements in the CDF, etc. The layout plan would be refined as the design is developed.*

Dike and Containment Design

Conventional geotechnical design of the main retaining dike is needed, but should be closely coordinated with the storage capacity and contaminant pathway evaluations. Specific design features for the main retaining dike may be required for contaminant pathway control.

Recommended Work Plan Elements:

- *Identify structural and/or geotechnical design requirements for the retaining dike and CDF as whole that would preclude or constraint modifications for CDF operations or contaminant pathway control.*

Volumetric Capacity

Filling is anticipated to be in two stages. First stage filling will be bottom dumping from barges into a partially diked CDF. This is essentially open water placement. The sizing for this phase (i.e. how much volume will be occupied by a given insitu dredged volume) is largely a consolidation evaluation. Second stage filling will be by mechanical rehandling from the barges to the CDF.

Recommended Work Plan Elements:

- *Conduct consolidation tests on composite samples of sediments from the dredging horizon.*
- *Determine consolidation behavior of the fill.*

Contaminant Releases from Barge Bottom-Dumping

If the initial fill is by barge bottom-dump, an evaluation of the contaminant release due to this filling method would be required. Procedures are available in the *Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. - Testing Manual (Inland Testing Manual)* (USEPA/USACE 1998).

Recommended Work Plan Elements:

- *Conduct Open Water Elutriate Tests (also called Standard Elutriate Tests) on composite samples from the dredging horizon slated for mechanical dredging and barge placement.*
- *Conduct modeling evaluations for prediction of contaminant release and dispersion using the USACE STFATE model and other models as required.*

CDF Contaminant Pathway Evaluations

If contaminated sediments are placed in a CDF, consideration of pathways for migration of contaminants from the site and potential contaminant impacts may be required. Contaminant migration pathways are routes by which contaminants or constituents of concern (COCs) associated with dredged material may move from the dredged material within the site into the environment outside the site.

A suite of evaluation procedures and laboratory test procedures has been developed by the USACE to evaluate CDF contaminant pathways. These procedures are presented in detail in *Evaluation Of Dredged Material Proposed For Disposal At Island, Nearshore, Or Upland Confined Disposal Facilities - Testing Manual (Upland Testing Manual).* (USACE 2003). From a technical standpoint, the procedures in the UTM are equally applicable to both navigation dredging and contaminated sediment remediation projects. The UTM presents both screening procedures to determine if a contaminant pathway is potentially an issue for a specific situation, and detailed testing and evaluation procedures to apply if needed.

Pathways for a nearshore CDF include a number of the pathways that are considered for upland CDFs. A primary advantage of the nearshore CDF is that contaminated dredged material may remain within the saturated zone so that anaerobic conditions prevail and contaminant mobility is minimized. A disadvantage is water level fluctuation via water level changes or other mechanisms, which cause a pumping action through the exterior dikes, which are generally constructed of permeable material. The pumping action may result in soluble convection through the dike in the partially saturated zone and soluble diffusion from the saturated zone through the dike.

Contaminant Pathway Screening

The possible pathways from an upland CDF include:

1. Effluent discharges to surface water during filling operations and subsequent settling and dewatering.
2. Precipitation surface runoff.
3. Leachate into groundwater.
4. Volatilization to the atmosphere.
5. Direct uptake by plants and animals living on the dredged material and subsequent cycling through food webs.

Evaluations can be conducted using a tiered framework in the UTM, with the initial tiers used as a screening tool based on sediment contaminant concentrations of the materials to be placed in the CDF. It is anticipated that the surface runoff, plant uptake, and animal uptake pathway screens would determine that no detailed evaluations would be needed, since a cover will be placed over the CDF and the site will be managed for use by the port following final filling. The contaminants of concern include PAHs, but concentrations are sufficiently low that volatilization can likely be screened from further testing.

Contaminant pathway tests in later tiers would determine if contaminant controls should be included in the CDF design. It is anticipated that pathway testing for effluent discharges and leachate flow through the dikes and side walls of the CDF will be required.

Recommended Work Plan Elements:

- *Pathway screening should be conducted for all pathways using the Tier 1 procedures in the UTM.*
- *Develop a sampling scheme and testing plan for pathway tests as warranted by the Tier 1 evaluation.*

Effluent Pathway and Controls

Effluent is defined as water discharged from a confined disposal facility (CDF) during and as a result of the filling or disposal of dredged material in the CDF (USACE/EPA 1992). Regardless of the manner in which a CDF is filled, and especially if the CDF contains water or is hydraulically filled, there will be an effluent.

CDFs are typically designed to retain virtually all the solid fraction of dredged material. However, all solids cannot be retained during the disposal process, and associated contaminants are transported in dissolved form and with the particles in the effluent.

Some CDFs may be designed to allow flow of effluent water through filter cells or permeable dike sections. The techniques described here may be applied to this case, but the influence of the filter media in retaining suspended particles and adsorption of contaminants from the effluent discharge should be considered.

Effluent Elutriate Tests (EETs) have been developed by the USACE for evaluation of water discharged from the CDF during filling (USACE 2003). EETs were conducted on 9 composite samples from the Consolidated Slip and will be used in evaluations of effluent for the CDF.

Recommended Work Plan Elements:

- *Develop predictions of effluent water quality using the USACE EFQUAL model and determine potential compliance with WQ standards.*

Leachate Flow Through Dikes and Foundations

Leachate is the water with associated dissolved and colloidal materials that seeps through dredged material in a CDF and subsequently through dikes or foundation material. Solid particles are not generally transported with the leachate and therefore the concerns for leachate quality are limited to the apparent dissolved (including fine colloidal fraction) concentrations of contaminant. The leachate pathway is perhaps the most technically complex to evaluate, yet it rarely is of environmental concern for contaminant migration because of the physical characteristics of most dredged materials, the nature of contamination, and the isolation characteristics common to most CDFs.

Standards for leachate water, especially that potentially seeping through dikes, and the point of compliance and allowable mixing will be especially important for the Berth 243-245 CDF. Drinking water standards should not be applied for evaluation of leachate from nearshore CDFs constructed near or adjacent to shorelines with underlying brackish or saline aquifers (which is presumably the case for Berth 243-245). In such cases, comparison of potential leachate with applicable surface water standards would be more appropriate.

The UTM contains procedures for conducting batch and column leach tests that were specifically designed for evaluation of sediments. The main purpose of leachate tests is to allow evaluation of the leachate pathways to hopefully prove that controls such as liners or leachate collection systems are not required for the Berth 243-245 CDF.

Recommended Work Plan Elements:

- *An evaluation of present hydrogeological conditions surrounding the CDF will be made to characterize groundwater flows conditions at the site. An initial evaluation will based on existing data, and additional data will be collected if needed for verification.*
- *Conduct column and batch leach tests (SBLTs and PCLTs) on composite samples of sediments from dredging horizons slated for both mechanical and hydraulic offloading/filling.*
- *Evaluate leachate quantity and quality and determine compliance with leachate quality standards considering flow behavior and attenuation in CDF dikes and sidewalls.*

CDF Monitoring Plan

A Monitoring Plan should be developed to ensure the various performance standards related to performance of the CDF are met. The general components of the monitoring plan would be similar to that for dredging monitoring, i.e. monitoring equipment and techniques, protocols for sampling, handling and testing, a description of how the monitoring data will be interpreted, and a corresponding management plan. CDF monitoring would typically include collection of turbidity and effluent samples during filling and collection of samples from monitoring wells for evaluation of leachate.

Recommended Work Plan Elements:

- *Development of a preliminary CDF monitoring plan to include recommended sampling and evaluation approaches, monitoring equipment and techniques, and management actions.*

Capping at Consolidated Slip

Capping Definitions

***In-Situ* Capping** is defined as the placement of an engineered subaqueous cover, or cap, of clean isolating material over an *in-situ* deposit of contaminated sediment. Capping of subaqueous contaminated sediments is an accepted engineering option for managing dredged materials and for *in-situ* remediation of contaminated sediments (Palermo et al., 1998a, 1998b; and USEPA 2005). *In-situ* caps are generally constructed using granular material, such as clean sediment, sand, or gravel, but cap designs can include geotextiles, liners, reactive materials, and multiple layers. Such engineered caps are also called isolation caps.

***In-situ* Capping with Partial Removal** is an option involving placement of an ISC over contaminated sediments which remain in place upon completion of a partial dredging action. In this case, ISC involves the removal of contaminated sediment to some depth followed by ISC of the remaining sediment. This is the anticipated case for the marina area of the Consolidated Slip. When ISC is used with partial dredging, the cap is designed as an engineered isolation cap, since a portion of the contaminated sediment deposit is not dredged and remains in place. This would be the case for the marina portion of the Consolidated Slip project.

Detailed guidance for ISC for sediment remediation has been developed by the U.S. EPA. The documents Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (EPA, 2005) and Guidance for In-Situ Subaqueous Capping of Contaminated Sediments (Palermo et al., 1998b), provide detailed procedures for site and sediment characterization, cap design, cap placement operations, and monitoring for subaqueous capping. These guidance documents should serve as the technical basis for the cap evaluations for the Consolidated Slip Project.

Cap Functions and Processes

In-situ caps must be considered engineered projects, designed to meet specific functions and performance objectives. The design must consider the nature of the site and all processes acting at the site, which may influence the cap from the standpoint of its physical stability and its ability to isolate contaminants.

Based on the project objectives, the functions for a cap in marina portion of Consolidated Slip may include one or more of the following:

- Physical isolation of the contaminated sediment from the aquatic environment;
- Stabilization of contaminated sediment, preventing resuspension and transport of contaminants; and,

- Reduction of the flux of dissolved and colloidally transported (i.e., facilitated transport) contaminants into surface cap materials and the overlying water column;

This design for In-Situ Capping (ISC) for the Consolidated Slip project therefore focuses on physical and chemical isolation of residual contamination in the canal following a partial dredging operation.

It is anticipated that the desired functions of the cap will include both physical stability and chemical isolation. It can be assumed that the cap would incorporate an armor layer at the surface consisting of a coarse sand, gravel or stone material and an underlying sand layer for isolation. Depending on the required armor size, a filter layer may also be required. And, depending on resource agency requirements, a habitat component for the design may be considered.

Conceptual illustrations of the Consolidated Slip project have shown the cap thickness as 5.0 feet. However, detailed cap design evaluations will undoubtedly result in a thinner required cap thickness.

Cap Performance Standards

Performance standards for the cap must be defined for the design effort. Standards related to physical stability could be set in terms of no movement of material for design events such as storms or prop wash. Standards related to chemical isolation could be set in terms of an acceptable rate of flux reduction, maintenance of water quality standards, or a limiting sediment concentration in the upper layers of the cap in the long term (with corresponding points of compliance).

Recommended Work Plan Elements:

- *Cap Performance Standards should be initially defined in early phases of evaluation at least in general terms, and the standards should be refined and finalized in more specific terms in the later phases.*

Site Conditions at Consolidated Slip Related to Capping

General categories of site conditions that should be considered in cap design include:

Water Depths and Bathymetry. The bathymetry data are available and should be adequate for design.

Sedimentation. The accumulation rate of fine sediments in the marina portion of Consolidated Slip should be defined for purposes of cap design.

Hydrodynamic Conditions. Modeling has been conducted for the Consolidated Slip project as a part of the channel design. This effort has likely defined the hydrodynamics in the marina under flood flow conditions.

Hydrogeological Conditions and Groundwater Flow. An evaluation of groundwater flow velocities into the marina portion of Consolidated Slip (post dredging) will be needed for cap design.

Presence of Debris. The presences of large debris is a major consideration for both dredging and capping.

Vessel Traffic. The vessel usage of the channel and marina should be defined to assess potential for prop wash. This would include vessel sizes, drafts, horsepower, anchoring, etc.

Recommended Work Plan Elements:

- *Conduct a detailed review of site conditions for the post-dredging marina portion of Consolidated Slip based on existing information and identify data gaps.*
- *Design any additional site investigations that may be required.*

Approach for Cap Design

The general steps for ISC design include the following:

- Identify candidate capping materials and compatibility with contaminated sediment at the site;
- Assess the bioturbation potential of bottom-dwelling organisms that would likely populate a cap or habitat layers on top of an isolation layer, and design a cap component to physically isolate sediment contaminants from them;
- Evaluate the potential erosion at the capping site due to currents, waves, ice scour, and propeller wash, and design a cap component to stabilize the contaminated sediment and other cap components;
- Evaluate the potential flux of sediment contaminants, and design a cap component to reduce the flux of dissolved contaminants into the water column and to reduce the surficial sediment concentrations at the top of the cap or habitat layer;
- Evaluate the potential interactions and compatibility among cap components, including mixing and consolidation of compressible materials;
- Evaluate the operational considerations and determine restrictions or additional protective measures (e.g., institutional controls) needed to ensure cap integrity; and
- Evaluate the need for long-term monitoring of cap effectiveness and develop a plan for implementation.

Cap Material Sources

Caps are generally composed of clean granular materials, such as sediment or soil; however, more complex cap designs could be required to meet site-specific objectives. The design should consider the need for effective short- and long-term chemical isolation of contaminants, bioturbation, consolidation, erosion, and other related processes. For example, if the potential for erosion of the cap is significant, the cap thickness could be increased using a material with larger grain size, or an armor layer could be incorporated into the design. A cap composed of naturally occurring sand is generally preferred over quarry run sand, because the associated fine fraction and organic carbon content found in natural sands are more effective in providing chemical isolation by sequestering contaminants as they pass through the cap. A total organic carbon (TOC) content for cap material of 0.5 percent by weight will result in adequate binding capacity for hydrophobic contaminants such as PCBs (Palermo et al., 1998a). It is anticipated that the POLA channel deepening project will be the source for capping sand.

It is anticipated that sand for the isolation cap layer can be obtained from borrow sources within reasonable distance of Consolidated Slip. It is anticipated that armor gravel or stone can be obtained from Catalina Island.

Recommended Work Plan Elements:

- *Summarize and determine the acceptability of cap material sources for purposes of analysis.*

Cap Components

The total thickness of a cap and the composition of the cap components is based on an evaluation of all the pertinent processes for the site and the ability of the design to achieve the intended functions of the cap. Processes that should be normally be considered for the cap design include bioturbation, cap consolidation, erosion, operational factors, and chemical isolation. For cap design with a granular material, a conservative "layer approach" should be used as recommended by USEPA (Palermo et al 1998 and USEPA 2005). Each component is considered and appropriately evaluated, and the necessary cap thickness is assumed as the sum of the layers for each component.

For an armored cap with the surface layer composed of coarse sand, gravel, or stone, the erosion protection layer may also act effectively as the bioturbation component, so a dual function is acceptably conservative for that layer.

Bioturbation. Aquatic organisms that live in or on bottom sediment can greatly increase the migration of sediment contaminants upward into the cap through bioturbation. The depth to which species will burrow is dependent on the species' behavior and the characteristics of the substrate (e.g., grain size, compaction, and organic content). In general, the depth of bioturbation by marine organisms is greater than that of freshwater organisms. The thickness of the surface layer must therefore exceed the bioturbation depth for organisms likely to recolonize the canal following cap construction.

The types of organisms likely to colonize a capped site and the normal behavior of these organisms is generally well known. The technical report, *Subaqueous Cap Design: Selection of Bioturbation Profiles, Depths and Process Rates* (Clarke and Palermo, 2001), in addition to providing information on designing ISCs, also provides many useful references on bioturbation.

Work Plan Elements:

- *Locally knowledgeable experts should be consulted and a written review prepared providing information on the aquatic organisms (and their bioturbation behavior, especially bioturbation depths) that will likely recolonize the marina following dredging/capping.*

Physical stability/erosion. The cap component for stabilization/erosion protection has a dual function. This component of the cap is intended to stabilize the contaminated sediment being capped, and prevent the sediment from being resuspended and transported off site. The potential for erosion may be a function of current velocity forces due to the storm events, wave-induced currents considering orientation of the marina to prevailing winds, and propeller-induced scour.

A detailed analysis of the armor layer requirements must be conducted as a part of the final cap design. This type of analysis should be based on the controlling shear stress due to the various erosion forces and required grain size for stability. The analysis should include an evaluation of a 100-year flow event, 100-year wind event, and use of an appropriate design vessel(s) for prop wash.

Recommended Work Plan Elements:

- *Conduct modeling (or review existing modeling efforts) to determine erosive forces due to flood flows.*
- *Conduct modeling to determine erosive forces due to wind-generated waves.*
- *Conduct a prop wash modeling study to determine erosive forces due to the design vessel(s).*
- *Determine the required cap armor material size distribution and thickness and any filter layer requirements.*

Consolidation. Potential consolidation of the underlying materials may influence the cap design, Since most contaminated sediment is highly compressible, the underlying contaminated sediment layer will almost always undergo consolidation due to the added weight of capping material or armor stone, and in this case, the proposed rock dike. Gravel, sand, or stone materials are not compressible, so no consolidation of the cap itself can be assumed. However, an analysis of consolidation of the underlying contaminated sediments should be conducted as a part of the evaluation of the chemical isolation cap component (see discussion below).

The marina portion of Consolidated Slip will be partially dredged prior to capping. This will relieve the overburden pressure on the sediments, and the subsequent placement of the cap material should result in a minimal increase in pressure. The magnitude of consolidation should therefore be comparatively low.

The degree of consolidation of the underlying contaminated sediment will provide an indication of the volume of water expelled by the contaminated layer and capping layer due to consolidation. This can be used to estimate the movement of a front of pore water upward into the cap. Such an estimate of the consolidation-driven advection of pore water should be considered in the evaluation of contaminant flux. Methods used to define and quantify consolidation characteristics of sediment and capping materials, such as standard laboratory tests and computerized models, are available (Palermo et al., 1998a, 1998b).

Work Plan Elements:

- *Conduct consolidation tests on the sediment horizons underlying the marina cap.*
- *Determine consolidation behavior of sediments underlying the cap for use in the cap isolation layer design.. This can be evaluated using the USACE Primary and Secondary Consolidation and Desiccation of Dredged Fill (PSDDF) model and/or the WES RECOVERY/CAP model.*

Chemical Isolation. If a cap has a properly designed physical isolation component, contaminant migration associated with the movement of sediment particles should be controlled. However, the movement of contaminants by advection (flow of pore water) upward into the cap is possible, while movement by molecular diffusion (across a concentration gradient) over long periods is inevitable. Since isolation of the contaminated sediments is a goal for the project, an evaluation of contaminant flux and chemical isolation effectiveness of the cap will be required.

Diffusion is the process whereby ionic and molecular species in water are transported by random molecular motion from an area associated with high concentrations to an adjacent area associated with a low concentration. Although diffusion is a very slow process, diffusion-driven mass transport will always occur if concentration gradients are present. Consequently, diffusion can transport contaminants through a saturated porous media in the absence of advection.

Advection refers to the flow of sediment pore water or underlying groundwater. Advection can occur as a result of compression or consolidation of the contaminated sediment layer or other layers of underlying sediment. Advection of pore water due to consolidation would be a finite, short-term phenomenon. Advection can also occur long-term as an essentially continuous process if there is an upward hydraulic gradient due to groundwater flow. Contaminants can be transported by advection as dissolved or particle-bound concentrations (e.g., ligand-sorbed colloids).

Several testing approaches have been applied to define cap thicknesses and the sediment parameters necessary to model their effectiveness in chemical isolation (essentially partitioning coefficients). Laboratory tests may be used to define sediment-specific and capping material-specific values of diffusion coefficients and partitioning coefficients. Although no standardized laboratory test or procedure has yet been developed to fully account for advective and diffusive processes and their interaction, both diffusion tests and batch and column tests for advective processes have been applied for cap designs.

Several numerical models (both analytical and computer models) are available to predict long-term movement of contaminants into or through caps due to advection and diffusion processes. The results generated by such models include flux rates and sediment pore water concentrations as a function of time. These results can be compared to applicable water quality criteria, or interpreted in terms of a mass loss of contaminants as a function of time. The models can evaluate the effectiveness of varying thicknesses of granular cap materials with differing properties (grain size and TOC). The USACE has developed a comprehensive model called RECOVERY/CAP that allows consideration of a varying sediment profile and both advective and diffusive processes. Results from consolidation evaluations can be incorporated in RECOVERY/CAP to consider consolidation-induced advection. This model should be considered for evaluation of the chemical isolation effectiveness as a part of the cap design.

Recommended Work Elements:

- *Conduct pore water analyses and/or batch or column tests on composite samples from the sediment horizon underlying the cap.*
- *Determine advective flow velocities (groundwater upwelling velocities) at the marina needed for flux modeling.*
- *Conduct cap effectiveness modeling to determine the isolation cap component thickness. This can be done using the WES RECOVERY/CAP model.*

Operational Components. Cap design should also allow for operational components for cap and sediment mixing and variability in placed cap thicknesses for both the sand and armor layers. These component thicknesses will be determined based on past experience with other projects.

Geotechnical Considerations

Geotechnical considerations important to cap design include shear strength of the contaminated sediments (which determine their ability to support a cap), and liquefaction issues for seismically active areas. The Consolidated Slip marina cap will not be constructed on a slope, but the edges of the cap at the marina entrances will be adjacent to and presumably covering slopes. The marina is in a high seismic risk area, so an assessment of slope stability at the marina entrances is recommended.

Usually, contaminated fine-grained sediment is predominately saturated and therefore has low shear strengths. These materials are generally compressible. Unless appropriate controls are implemented, contaminated sediments can be easily displaced or resuspended during cap placement. Usually, gradual placement of capping materials over a large area will reduce the potential for localized failures. The removal of sediments prior to capping will leave the pre-cap sediment surface at a higher shear strength, and this should further reduce potential problems with mixing or displacement during cap construction.

Field monitoring data have shown successful sand cap covering of contaminated sediment with low strength. For example, a cap should be built up gradually over the entire area to be capped. This will reduce the potential for mixing and overturning of the contaminated sediment. The cap placement approaches described below allow for such controlled placement.

A bearing capacity analysis can be used to determine the allowable differential lift thickness during cap placement to ensure against displacement failures.

Recommended Work Elements:

- *Obtain shear strength data for the sediment horizon lying below the marina cap.*
- *Assess needs for and conduct as needed slope stability analyses for the marina cap to include consideration of seismic risk.*
- *Conduct a bearing failure analysis to determine the allowable differential lift thickness during cap construction.*

Cap Placement Techniques

A variety of equipment types and placement methods have been used for capping projects (Bailey and Palermo 2005). This has included the use of hopper barges at larger, open-water sites, and both hydraulic and mechanical systems for placement at nearshore or shallow-water sites. Important considerations in selection of placement methods include the need for controlled, accurate placement of capping materials. Slow, uniform application that allows the capping material to accumulate in layers is often necessary to avoid displacement of or mixing with the underlying contaminated sediment.

Granular cap material such as sands and gravels can be handled and placed in a number of ways. Mechanically dredged materials and soils excavated from an upland site or quarry have relatively little free water. These materials can be handled mechanically in a dry state until released into the water over the contaminated site. Mechanical methods (such as clamshells or release from a barge) rely on gravitational settling of cap materials in the water column, and could be limited by operational depths in their application.

Granular cap materials can also be entrained in a water slurry and carried to the contaminated site wet, where they are discharged into the water column at the surface or at depth. These hydraulic methods offer the potential for a more precise placement, although the energy required for slurry transport could require dissipation to prevent resuspension of contaminated sediment. Armor layer materials of larger size can be placed from barges or from the shoreline using conventional equipment, such as clamshells.

Recommended Work Elements:

- *Review site conditions and past project experience in the POLA and develop options for cap material placement for use in design and cost estimating.*

Contaminant Release During Cap Placement

Even though there are no standardized methods to predict the degree of contaminated sediment resuspension resulting from cap placement, field data provide some insight on this process. EPA has conducted monitoring of capping-induced resuspension for projects at Eagle Harbor and Boston Harbor. Capping resuspension was low for both of these sites and decreased as capping operations continued. Similar results were also found for capping resuspension monitored for a large-scale capping field pilot study at the Palos Verdes site, where contaminant concentrations quickly returned to background levels. Extensive water quality monitoring of capping-induced resuspension conducted for the Soda Lake project found no detections of site-related petroleum hydrocarbons. The overall results from these studies indicate that levels of sediment resuspension due to well-managed capping operations were acceptable and comparable to those for well-managed environmental removal projects. Measures to reduce the potential for resuspension, volatilization, or other contaminant movement should include selection of cap materials, placement equipment, and methods designed to spread the capping material over the site gradually.

Institutional Controls

Once the capping project is complete, some institutional controls on use of the marina will be necessary to ensure long-term integrity of the cap. These may include restrictions on the sediment bed (analogous to traditional "deed restrictions" for a land-based project), as well as possible "water use" restrictions. This may include restrictions on setting utility or cable corridors, construction of fixed-post docks, or any other construction activity that would otherwise disturb the integrity of the cap. Water use restrictions might include limits on vessel size, anchoring, or propeller size. The institutional controls should be identified and memorialized as part of a detailed, long-term maintenance plan.

Cap Monitoring

A monitoring program should be required as a part of any capping project design. The main objectives of monitoring for ISC would normally be to ensure that the cap is placed as intended and that the cap is performing the basic functions (physical isolation, sediment stabilization and chemical isolation) as required to meet the remedial objectives. The need for a Long Term Monitoring and Management Plan should be described and the costs of the plan included in cost estimates for the cap design.

Specific items or processes that may be monitored include cap integrity, thickness, and consolidation, the need for cap nourishment, benthic recolonization, and chemical migration potential. Intensive monitoring is necessary at capping sites during and immediately after construction, followed by long-term monitoring at less frequent intervals. In all cases, the objectives of the monitoring effort and any management or additional remedial actions to be considered as a result of the monitoring should be clearly defined as a part of the overall project design. The cost and effort involved in long-term monitoring and potential management actions should be evaluated as part of the project cost estimates.

Monitoring programs for Simpson, Eagle Harbor, Soda Lake, and other projects have included components for resuspension and cap integrity during construction as well as components for long-term cap effectiveness. Plume monitoring with instruments as well as discrete samples for contaminant concentrations are the usual approaches for resuspension monitoring. Pre- and post-bathymetric surveys, along with consolidation measurements, help evaluate whether cap thickness design objectives are achieved. Cores taken through the cap are the most frequent tools used to determine cap integrity during and immediately following construction as well as at longer time intervals for purposes of long-term effectiveness. Samples from the cores are analyzed for both physical parameters as well as sediment and/or pore water chemistry. It is especially important that clean placement of the upper layer of the cap be confirmed by monitoring. Any construction monitoring to determine this needs to occur PRIOR to placement of the armor layer. For long-term monitoring for effectiveness, sediment samples should be taken in the lower portions of the cap profile in addition to the upper biologically active zone. This will determine if any contamination in the cap is due to cap performance issues (migration from below) or recontamination from above. This is especially important for the Consolidated Slip project because of the potential for recontamination.

Recommended Work Plan Elements:

- *Development of a preliminary cap monitoring plan to include recommended sampling and evaluation approaches, monitoring equipment and techniques, and management actions.*

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